MEASURES AND COMPARISONS OF NATIONAL RESOURCES FOR R&D

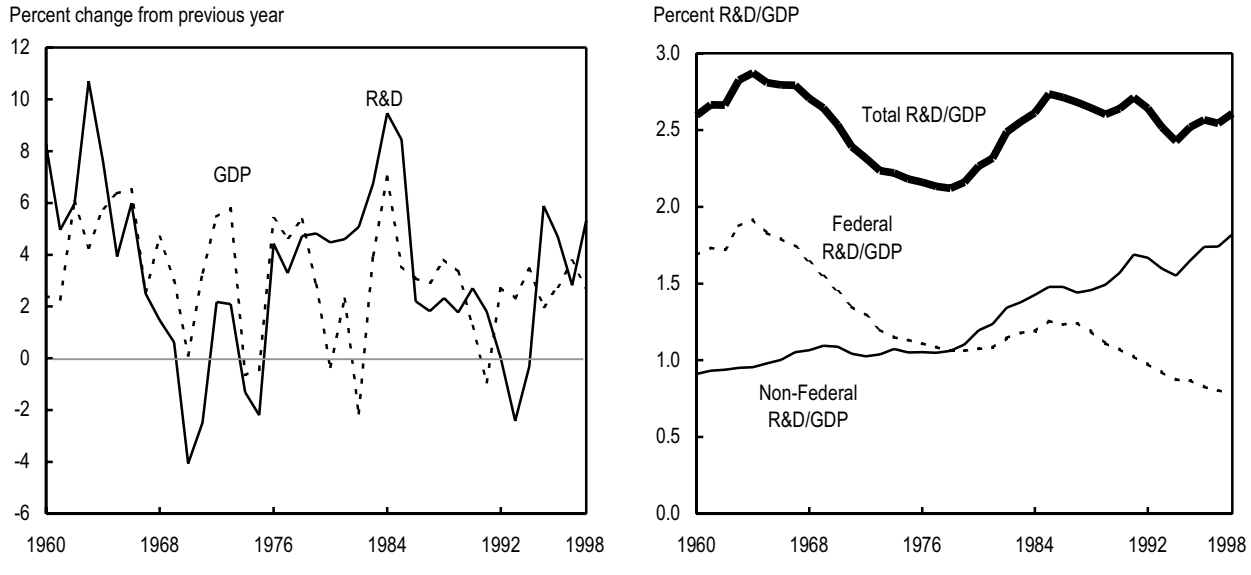
This section examines two indicators of R&D spending: (1) the ratio of total R&D expenditures to GDP, and (2) the ratio of Federal funds expended for R&D to total Federal funds. Also presented is a comparison of U.S. R&D resources with those of other countries. These measures and comparisons show that growth in total U.S. R&D expenditures is now accelerating, after a period of relatively slow growth in the early 1990s. In 1980–85, annual R&D growth had been much higher, averaging 6.8 percent in real terms. That rate then slowed to 2.2 percent in 1985–90, and to 0.9 percent in 1990–95. However, annual real R&D growth in 1995–98 is expected to average 4.3 percent (figure 6). Almost all of the recent growth in national R&D expenditures is the result of a resurgence of industrial R&D. In comparison to its major international competitors, the U.S. appears, by preliminary estimates, to be taking the lead at expanding R&D efforts, while the other nations appear to be experiencing near-zero growth in R&D in real terms.

U.S. R&D/GDP RATIO

Growth in R&D expenditure should be examined in the context of the overall growth of the economy, because, as a part of the economy itself, R&D is influenced by many of the same factors, such as population changes, capital accumulation, and technological advancement. For instance, if population and physical capital each increase by 5 percent from one year to the next, causing the GDP to rise by 5 percent as well, then one would expect, assuming nothing fundamental has changed, that R&D expenditures would also rise by 5 percent. Conversely, if R&D is not observed to grow at the same rate as GDP, then fundamental changes are likely taking place. Furthermore, the ratio of R&D expenditures to GDP may be interpreted as a measure of the Nation's commitment to R&D.

A review of U.S. R&D expenditure as a percent of GDP over time shows an initial low of 1.36 percent in

Figure 6. Annual changes in GDP and R&D, and the R&D/GDP ratio: 1960–98 (based on constant 1992 dollars)



NOTE: Data are preliminary for 1997 and 1998.

SOURCE: National Science Foundation/Division of Science Resources Studies; tables B-5 and B-6.

1953, rising to its highest peak of 2.87 percent in 1964, followed by a gradual decline to 2.12 percent in 1978. From the low in 1978, U.S. R&D expenditures rose steadily again to a peak of 2.74 percent in 1985, and did not fall below 2.6 until 1993. In 1994, the rate dropped to 2.43, the lowest it had been since 1981. Starting in 1994, however, R&D/GDP has been experiencing an upward trend. As a result, the current expected ratio of 2.61 for 1998 is the highest the ratio has been since 1992.[13]

The initial drop in the R&D/GDP ratio from its peak in 1964 largely reflected Federal cutbacks in defense and space R&D programs, although gains in energy R&D activities between 1975 and 1979 resulted in a relative stabilization of the ratio at around 2.2 percent. Over the entire 1965–78 period, the annual percentage increase in real R&D was less than the annual percentage increase in real GDP. In years that real R&D spending decreased during that period, real GDP also fell, but at a lower rate (figure 6).

The rise in R&D/GDP from 1978–85 was as much due to a slowdown in GDP growth as to increased spending on R&D activities. For example, the 1980 and 1982 recessions resulted in a slight decline in real GDP, while there was no corresponding reduction in R&D spending. During previous recessions, changes in funding for R&D tended to match or exceed the adverse movements of the broader economic measures.

R&D/GDP then went from 2.74 percent in 1985, to 2.60 percent in 1989, and back up to 2.71 percent by 1991. Again, the ratio tended to fall when GDP experienced relatively fast real growth and rise when it experienced relatively slow real growth. Nevertheless, R&D itself was also affected. The share of R&D that was defense related dropped from 29.9 percent in 1985 to 22.5 percent in 1991. Commensurate with this change was the sharp fall in the share of R&D that was federally funded, from 45.9 in 1985 to 37.7 in 1991. This decline in Federal funding was counterbalanced by increased industrial funding, as described above in the discussion of industrial trends.

With regard to the R&D/GDP ratio, the period from 1991–98 in some respects mirrors the period from 1985–91. Both began with a "local maximum" (a maximum with respect to the few years both before and after the year in question), then experienced a local minimum in roughly the middle of the period, and an upturn thereafter to a new local maximum. Thus, 1991 began with a ratio of 2.71 percent, fell to 2.43 in 1994, and rose again to 2.61 percent in 1998 by preliminary estimates. As in the 1985–91 period, the 1991–98 period experienced the greatest fall in R&D/GDP (from 2.52 in 1993 to 2.43 in 1994) when GDP experienced high growth, from $6,558 billion to $6,947 billion, or 3.46 percent growth in real terms.

U.S. Federal R&D Funds/Total Budget Ratio

One way to gauge the U.S. Government's priority for R&D is to compare Federal outlays for R&D with Federal outlays for all purposes.[14] Total Federal outlays (for on-budget programs only) for fiscal year (FY) 1998 are estimated at $1.348 trillion.[15] R&D is expected to account for 5.29 percent ($71.4 billion) of those total outlays (figure 7 and appendix table B-11).

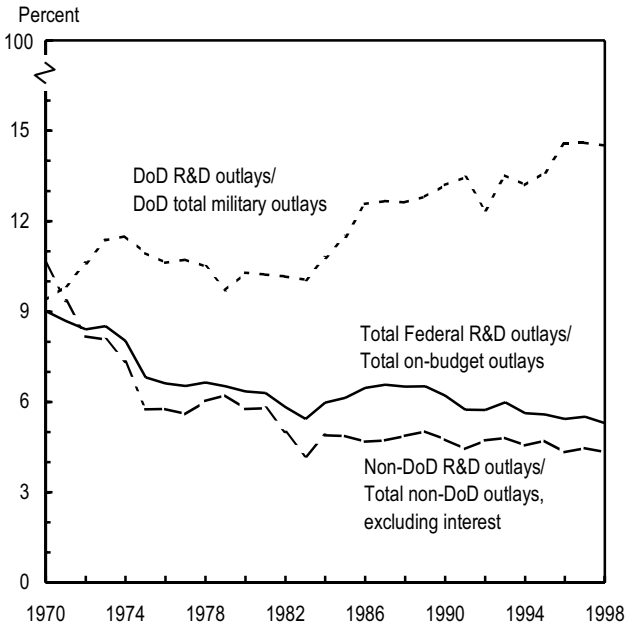
From FYs 1970–83, R&D outlays as a percent of total outlays declined steadily, especially during the early seventies, dropping from 9.0 to 5.4 percent. This trend was dominated by a sharp fall in non-DoD R&D outlays as a proportion of all non-DoD outlays (excluding interest on the national debt), which ranged from 10.6 percent in FY 1970 to 4.2 percent in 1983. In contrast, throughout the same period, R&D funded by the Defense Department as a proportion of total DoD outlays went from a low of 9.4 percent in 1970, to a peak of 11.5 percent in FY 1974, to 10.1 percent by 1983. The declining share of non-DoD R&D was not confined to one or two agencies but was a result of both slow growth in most non-DoD agencies' R&D outlays and a relatively rapid expansion of the non-R&D component of the Federal budget for civilian agencies.

[13] See Payson, S., "R&D as a Percent of GDP Is Highest in Six Years," Division of Science Resources Studies, *Data Brief*, National Science Foundation, NSF 99-302.

[14] This idea is applicable in most years. However, in exceptional years in which there are extenuating circumstances, like a major war, Federal outlays for purposes other than R&D may reflect those extenuating circumstances rather than "the government's priority for R&D."

[15] Almost all off-budget receipts and disbursements are for social security programs (the Federal Old-Age and Survivors Insurance and the Federal Disability Insurance trust funds), which are excluded from the budget totals by the Balanced Budget and Emergency Deficit Control Act of 1985. Preliminary off-budget outlays for FY 1998, as provided in the President's 1999 budget proposal, are $320 billion. See Office of Management and Budget, *The Budget of the United States Government, Fiscal Year 1999* (Washington, D.C.: U.S. Government Printing Office, 1998).

Figure 7. Ratio of Federal R&D outlays to total budget outlays: 1970–98



KEY: DoD = Department of Defense

NOTES: Excludes off-budget outlays, which are mostly for social security programs. Data are preliminary for 1997 and 1998. DoD R&D outlays are not strictly comparable to "defense R&D," as they do not include Department of Energy atomic weapons R&D.

SOURCES: National Science Foundation/Division of Science Resources Studies, Department of Commerce, and Office of Management and Budget, table B-11.

After FY 1983 the percentage of all Federal outlays devoted to R&D first rose and then fell. The ratio peaked at 6.6 percent in FY 1987, remained at 6.5 percent in FYs 1988–89, but fell steadily since then, to a preliminary level of 5.3 percent in FY 1998. Most of the increases in Federal R&D/total outlays in FYs 1984–86 were due to relatively large increases in DoD R&D outlays. Before 1990, this increase in DoD R&D was not offset by the relative decline in non-DoD R&D—as had been the case in the 1970s—or by the growing share of the Federal budget for interest payments.[16] In the 1990s, the declining R&D outlay ratio can be attributed to a relative decrease in non-DoD R&D as a proportion of non-DoD, non-interest, outlays. Concurrently, however, R&D has taken on relatively increasing importance in a shrinking DoD budget.

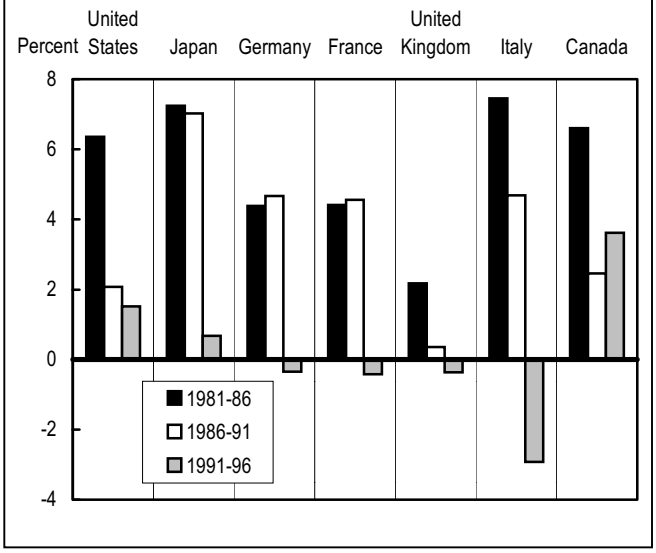
[16] As a percentage of total Federal on-budget outlays, interest payments on the national debt rose from 13.9 percent in FY 1983 to 19.4 percent in FY 1989. In FY 1998 the preliminary share of on-budget outlays for interest payments is 21.5 percent (see appendix table B-11).

International Comparisons

The R&D/GDP ratio discussed above can be used to determine the relative emphasis placed on R&D activities by the United States and other countries, which is not directly related to the total size of their economies. Another useful measure is to compare the number of R&D scientists and engineers in a country with its total labor force. Use of these ratios bypasses many of the problems in interpretation caused by inflation, exchange-rate fluctuations, different unit costs, and variations in the volume of research efforts. Caution must nonetheless be exercised in making even these international comparisons, because each country measures its R&D and personnel somewhat differently.

From 1991–96, total R&D expenditures stagnated or declined in six of the largest (group of seven) R&D-performing countries: the United States, Japan, Germany, France, United Kingdom, and Italy. In only Canada was consistently growing R&D the exception (figure 8), although, as noted above, R&D growth now is also accelerating in the U.S. Indeed, for more than a decade, these countries have displayed similar aggregate R&D trends: substantial inflation-adjusted R&D growth in the early 1980s, followed by a general tapering off in the late 1980s, and then level or declining real R&D expenditures

Figure 8. Annual rates of change in real R&D spending, for selected countries



NOTE: Rates of average annual change based on inflation-adjusted currencies. The rate shown for Japan is for 1991–95 due to unavailability of 1996 data.

SOURCE: National Science Foundation/Division of Science Resources Studies, table B-30.

into the 1990s. For most of these countries, economic recessions and general budgetary constraints had the effect of slowing both industrial and government sources of R&D support. In particular, both factors have contributed to the major reversal of R&D trends in Japan, where R&D spending has declined recently after experiencing inflation-adjusted gains of about 8 percent annually during the previous decade. The same is true for the United Kingdom and Italy, where real growth in the 1980s gave way to declining R&D expenditures after taking into account overall inflation.

Additionally, geopolitical changes have resulted in cutbacks in government support for defense-related R&D that, in turn, have reduced reported national R&D growth patterns in some countries, most notably in the United States and France. For Germany, the integration of the former East German science and technology system into that of West Germany's market economy resulted in an apparent jump in the nation's R&D effort in 1991, only to have been scaled back since in an effort to restructure and close inefficient, inappropriate, and redundant research institutions.[17]

R&D/GDP Ratios

Due to the size of its economy, the United States spends more on R&D than any other country, though it does not spend as high a proportion of its economy on R&D as some other countries.[18] In 1996 the most recent year for which comparable international data are available, the United States spent 2.57 percent of its GDP on R&D, compared to 2.77 percent spent by Japan in 1995 (the latest year's data available for that country), 2.32 percent by France, 2.28 percent by Germany, 1.94 percent by the United Kingdom, 1.66 percent by Canada, and 1.03 percent by Italy.

During the early to mid-1960s, the United States ranked highest among these countries in the R&D/GDP ratio. After 1964, however, the U.S. ratio began to decline, as Federal R&D spending for defense and space was cut back while the U.S. GDP continued to increase. At the same time, the ratios of other countries—notably (West) Germany and Japan—slowly increased. These trends continued until the late seventies, when the U.S. ratio had dropped to 2.2 percent and was roughly equal to those of (West) Germany, the United Kingdom, and Japan.

From the late seventies through the early eighties, the ratios in all of the industrialized countries just mentioned were again increasing, and by 1985 they had reached 2.74 percent for the United States, 2.72 percent for (West) Germany, 2.58 percent for Japan, 2.23 percent for the United Kingdom, and 2.25 percent for France. (See figure 9 and appendix table B-30). Since 1985, the R&D/GDP ratios of each of these countries have fluctuated within narrow ranges. Japan's ratio peaked at 2.85 percent in 1990 and then dipped back to 2.63 percent in 1994. The ratio for Germany peaked at 2.88 percent in 1987 but has since declined to 2.28 percent by 1996—a result, in part, of the reunification of Germany and its subsequent effects on official statistics. The R&D/GDP ratio for France rose continually from 1.97 percent in 1981 to a peak of 2.45 percent in 1993, but then fell to 2.32 percent by 1996, the lowest it has been since 1988. The British ratio remained between 2.11 and 2.25 from 1983–94, but since dropped to 1.94 percent by 1996.

Separation of R&D into defense and non-defense activities allows for the examination of the ratio of non-defense R&D to total GDP. In 1996, the most recent year for complete data, the United States had a non-defense R&D/GDP of 2.11 percent. This ratio was lower than for Germany (2.20) and Japan (2.73 in 1995), but higher than for France (2.04 in 1995), the United Kingdom (1.71), Canada (1.63), and Italy (0.98 in 1995). In 1995, the last year for which Japanese data are available, roughly 99 percent of Japanese R&D was devoted to nondefense activities, as compared with 81 percent for the United States.

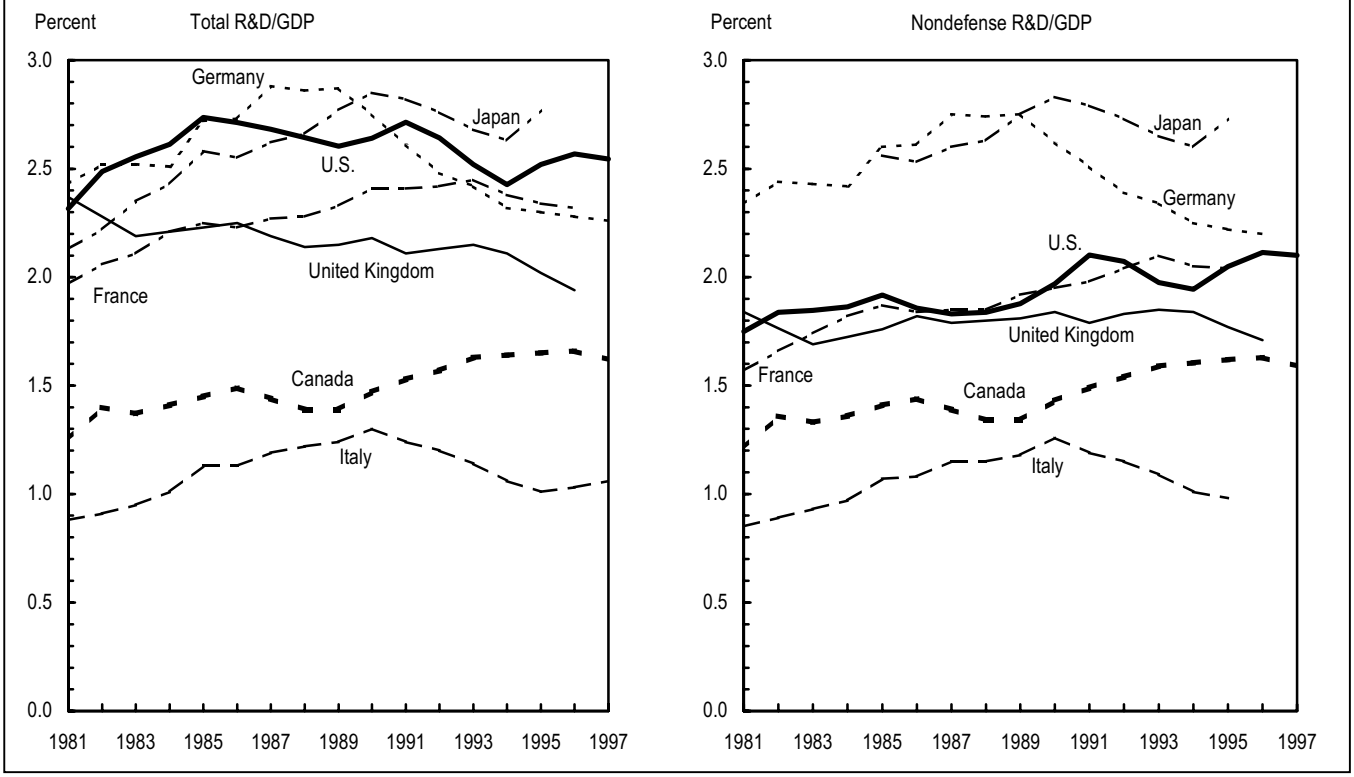
R&D Scientists and Engineers/ Labor Force Ratios

The estimated number of scientists and engineers employed in full-time-equivalent (FTE) R&D jobs, as a proportion of the total labor force, is higher in the United States and Japan than in the other industrialized market economies. For the United States, FTE R&D scientists and engineers (S&Es) as a percent of the labor force tended to rise between 1981 and 1991, from 0.62–0.76 percent, but has remained at 0.75 percent in 1993 and 1995 (the last year for which such data are currently

[17] For more detailed discussion of these changes, see National Science Board, *Science and Engineering Indicators—1998*. Arlington, VA: National Science Foundation, 1998 (NSB 98-1), pp. 4-35–4-55.

[18] Besides Japan (mentioned below), Sweden and Switzerland have also had higher R&D/GDP ratios than the United States. See, for example, National Science Foundation, *Human Resources for Science and Technology: The European Region*, NSF 96-316, Special Report, Arlington, VA, 1996.

Figure 9. R&D expenditures as a percentage of GDP, by country: 1981–97



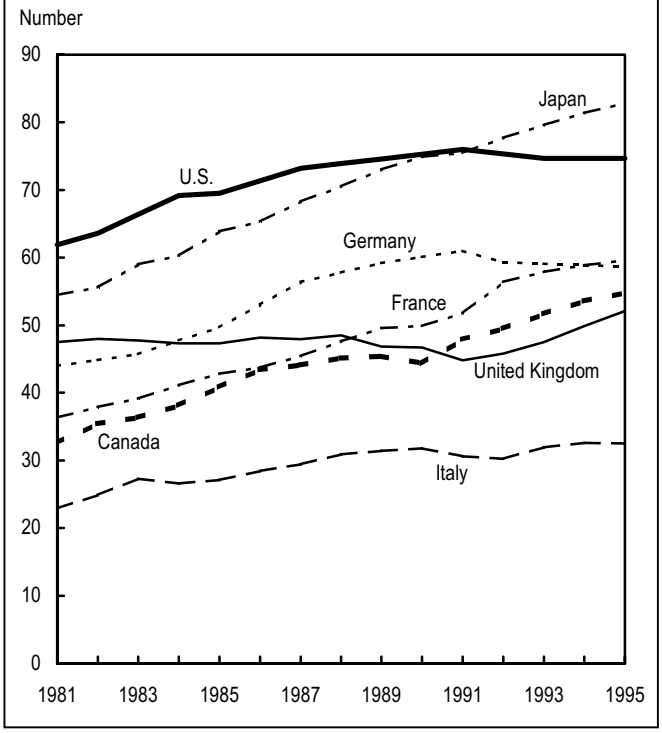
SOURCE: National Science Foundation/Division of Science Resources Studies, table B-30.

available). In 1993 Japan, with 0.80 percent, exceeded the United States in the percent of all employees that are R&D S&Es. This difference in the R&D S&E ratio between the United Sates and Japan is in sharp contrast to earlier values (figure 10). For example, in 1981, the percent was 0.62 for the United States and 0.55 for Japan.[19]

France and Germany also experienced significant increases: France from 0.36 percent in 1981to 0.58 percent in 1993, and Germany from 0.44 percent in 1981 to 0.59 percent in 1992 and again in 1995. In Canada, R&D S&Es increased from 0.33 percent of the labor force in 1981 to 0.55 percent in 1995. In contrast, the United Kingdom and Italy experienced relatively slower growth in this percentage, the U.K. growing from 0.48 percent in 1981 to 0.52 percent in 1995, and Italy growing from 0.23 percent in 1981, to 0.31 in 1988, but then increasing to only 0.33 percent by 1995.

[19] Japanese and U.S. surveys on the number of scientists and engineers engaged in R&D are not strictly comparable. Estimates for most of the U.S. data are adjusted to estimate full-time equivalence; Japanese surveys, on the other hand, ask for the total number of S&Es engaged in R&D regardless of the amount of time devoted to R&D. Japanese data on scientists and engineers exclude those engaged in R&D in the social sciences. The U.S. data exclude such personnel from the industry sector alone. The historical series for these U.S. personnel data was revised in this *National Patterns.* Data for 1985 and later years are not directly comparable with the data for 1984 and earlier years. See appendix A for a review of these changes.

Figure 10. Scientists and engineers engaged in R&D per 10,000 labor force, by country: 1981–95



SOURCE: National Science Foundation/Division of Science Resources Studies, table B-29.